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COMMON WHITE GRUBS

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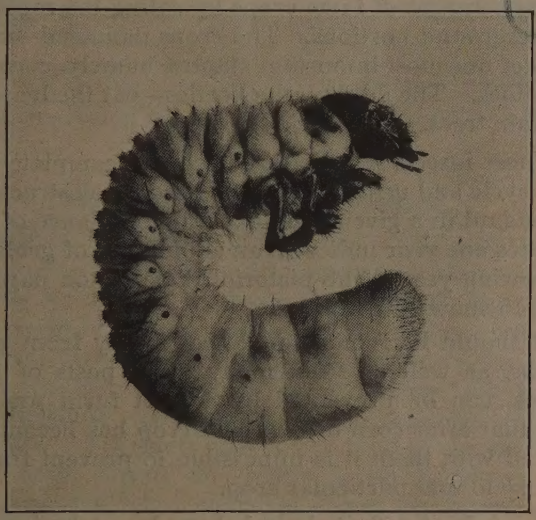

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UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

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WHITE GRUBS, the young of May beetles, are capable of devastating, and frequently destroy, large acreages of farm crops by eating the roots and underground portions. The crops damaged include two of our most important staples, namely, corn and potatoes. The adults—the beetles—eat the leaves of certain trees.

These insects require three years to complete their life cycle and usually only one brood is destructively abundant in a given locality. An abundance of May beetles one year indicates an abundance of grubs the following year. The pictorial diagram on pages 14 and 15 shows the life cycle.

It should be remembered that injury from white grubs, as well as from many other pests of farm crops, can be prevented by correct farm practice, but that after corn or any field crop has become infested with them it is impossible to prevent further injury to that particular crop.

Records of definite broods have been obtained for the Northern States and there it is possible usually to be warned one or more years in advance of their appearance.

For brief practical directions regarding what to do to combat each stage of the white grubs, consult the table on page 28.

COMMON WHITE GRUBS.

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WHITE GRUBS AND MAY BEETLES.

THE COMMON WHITE GRUBS, OR "GRUBWORMS" as they are often called (see title-page illustration and fig. 1), are the young of the May beetles or "June bugs" (fig. 2). They feed on the roots of various plants and the tubers of the potato (fig. 1) and have been recognized for years as serious pests, especially to corn and timothy, but also to the strawberry and potato, to recently transplanted roses, and to nursery plantings, particularly those of conifers. The adult insects (the beetles) eat the leaves of oak, ash, hickory, poplar, elm, willow, locust, hackberry, walnut, and other trees, and when abundant sometimes completely strip large tracts of timber. The most destructive work, however, is that of the grubs, which often results in the complete loss of crops where the outbreaks occur. Though grubs show a preference for certain food plants, from present information the grubs of different species do not appear necessarily to have different food habits. There are no authentic records of injury to such crops as alfalfa and clover, and from all observations small grains[2] are less attacked and injured than are corn, timothy, strawberries, beans, potatoes, and conifer seedlings.

OUTBREAKS OF WHITE GRUBS IN 1912 AND 1915.

Probably the most serious outbreaks of white grubs in the history of American agriculture occurred in 1912 and 1915, following an abundance of May beetles in 1911 and 1914, respectively. Injury was reported from almost every section of the country north of the Ohio

[1] *Lachnosterna* spp.

[2] Winter wheat is severely injured quite regularly in the fall of the year in Kansas and Oklahoma by white grubs of one of the plains May beetles (*Lachnosterna lanceolata* Say). This insect, however, has habits and life history quite different from those of the common May beetles under discussion.

FIG. 1.—White grub working in a potato tuber, Tabor, S. Dak., 1912.

River and westward to South Dakota (see fig. 3). In the West the center of abundance was in southwestern Wisconsin, while in the East it seemed to be located in northeastern Pennsylvania and southeastern New York. Infestation occurred, however, as far west as Tabor, S. Dak., and though no serious general injury was found west of eastern Iowa there were scattered occurrences in western Iowa and southern Minnesota. Throughout the southern third of Wisconsin and in northern Illinois the grubs were abundant, especially in the western portion of these sections. Many infestations were also reported from southern Michigan and scattered ones from northern Indiana and eastward through Ohio.

In the worst infested districts it was not unusual to find from 40 to 60 white grubs in a single hill of corn. Indeed, in a cornfield near McGregor, Iowa, which had been planted to timothy the previous year (1911), 77 2-year-old grubs were found in an area only 2½ feet square and 5 inches deep. This really represented an area less than that usually occupied by a single hill of corn, for the hills in this field were 3½ feet apart.

From a survey of the infested territory in Iowa (fig. 4), Wisconsin (fig. 5), and Illinois (fig. 6), made in 1912, and from reports of farmers and others, we have a very

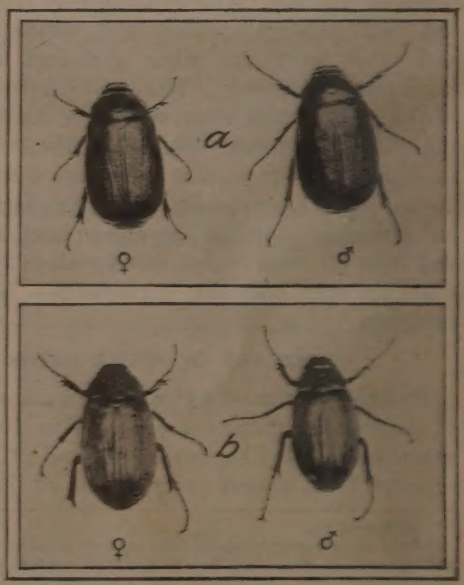


FIG. 2.—Typical examples of May beetles: *a*, *Lachnosterna anxia (dubia)*; *b*, *Lachnosterna ilicis*.

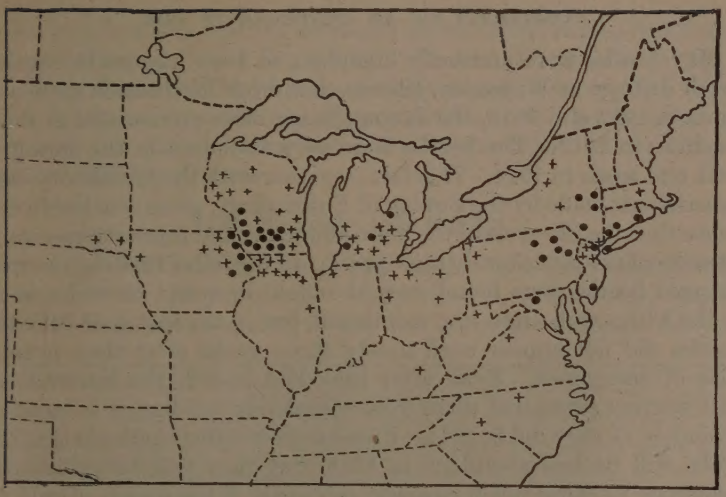


FIG. 3.—Map showing the invasion of white grubs in 1912. The black dots indicate counties known to have been generally infested; the crosses, those known to have been infested more or less.

conservative estimate of the damage to corn, timothy, and potatoes in these States aggregating not less than $7,000,000. The damage to the same crops in the other infested areas could not have been less than $5,000,000, which brings the total loss due to white grubs in 1912, exclusive of damage to strawberries, nursery stock, lawns, and miscellaneous crops, to not less than $12,000,000. A similar survey in 1915 showed a slightly smaller amount of apparent injury, although the beetles the preceding year were noticeably more abundant than in 1911 and the grubs were more numerous in 1915 than in 1912. The smaller amount of injury may be accounted for by the abnormally wet season which prevailed in this area in 1915, preventing the injury to crops and pastures which was so evident in 1912.

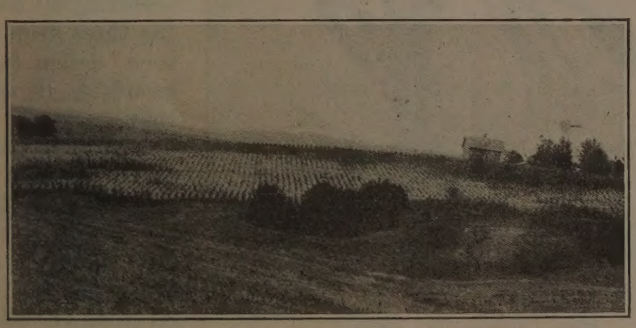


FIG. 4.—A 60-acre cornfield completely destroyed by white grubs, Farmersburg, Iowa, 1912.

POSSIBILITY OF AN OUTBREAK IN 1918.

May beetles were unusually abundant in 1908, the grubs causing much damage in Wisconsin, Illinois, and other localities in 1909 and again in 1912 and 1915, the damage being more pronounced in these localities in 1912. The beetles were very abundant in the spring of 1911 and again in 1914. This fact, together with the life-history cage experiments made by the Bureau of Entomology, gives conclusive evidence that the life cycle of the more abundant and injurious species in those localities is uniformly three years. In the fall of 1916 the recently changed beetles were found very abundant in newly plowed ground in the white-grub areas just mentioned, but in the spring of 1917 the beetles did not appear until nearly three weeks after their normal date of emergence. Even after they had issued, the intermittent cool weather prevented them from completely defoliating large areas of timber, as they did in 1914. Present observations indicate that the grubs will be less abundant in 1918, but they will be sufficiently numerous to cause much damage, especially if the season should be dry.

BROODS OF MAY BEETLES.

FIG. 5.—Individual corn hill showing characteristic white-grub injury, Platteville, Wis., August, 1915.

For the areas bounded roughly by the latitudes of northern Kentucky and southern Minnesota and from South Dakota on the west to Connecticut on the east the injurious and abundant species have a three-year life cycle, and the broods occurring in each of the three years have been designated as broods A, B, and C, respectively. The brood issuing as May beetles in 1914 and appearing as destructive grubs in 1915 is brood A (fig. 7). This is by far the most abundant of all

known broods and is the one discussed under the preceding headings. The second brood (brood B), of which the beetles appeared in 1915 and the grubs in 1916, is of little consequence at present. The third brood, known as brood C (fig. 8), was active in the beetle stage in 1916 and the grubs destructive and abundant in 1917 in a few comparatively small areas.

LIFE HISTORY AND HABITS.

All of the commoner species of May beetles have been reared from egg to adult at Lafayette, Ind. There the life cycle is three years, except in the case of several of the less important species. In the

FIG. 6.—Cornfield injured by white grubs, Seward, Ill., August, 1915.

latitude of northern Wisconsin, where grubs of May beetles[1] are destructive to young conifers, the cycle is four years, and in the southern latitudes of Texas the period from egg to adult seems to be two years for most species. In the case of all of the common species occurring at Lafayette and northward the grubs change to adults in the fall, passing the winter in the soil as beetles and emerging the following spring. In several species[2] occurring in the latitude of southern Indiana and southward (species which appear late in the season and after the early appearing May beetles have about disappeared)

[1] *Lachnosterna drakii* Kirby (*grandis* Smith) and *L. anxia* Le Conte (*dubia* Smith).
[2] *Lachnosterna ephelida* Say, *L. forbesi* Glasgow, *L. quercus* Knoch, and others.

pupation and subsequent emergence as adults takes place in the spring instead of in the fall.

A résumé of the life of the injurious generation of 1915 is as follows: Eggs (fig. 9) deposited by the female beetle in the spring of 1914 hatched three or four weeks later, and the young grubs fed the first season on decaying and living vegetable matter in the soil. As winter approached they protected themselves from the cold by burrowing deeper into the ground, remaining there inactive until the spring of the the following year (1915), when they returned to a position near the surface, feeding on the roots of such crops as were available. In this the second year they did the maximum amount of damage. In the fall they again went deep into the soil, returning near the surface of the soil in the spring of 1916, where they fed as before on the plant roots until about June. Thus two full years were passed in the grub stage in the soil (fig. 10) and during this time they molted twice previous to molting for the pupa stage. They then prepared oval earthen pupal cells in the ground, became more or less inactive, and later changed to the pupa or true dormant state (fig. 11). The adult beetles (fig. 2), which emerged from the pupæ a few weeks later, remained in the pupal cells over winter and emerged the following spring (1917) to feed and mate in the foliage of the trees and shrubs and to deposit their eggs in the soil for another generation. The complete life cycle of the insects is shown in diagram in figure 14.

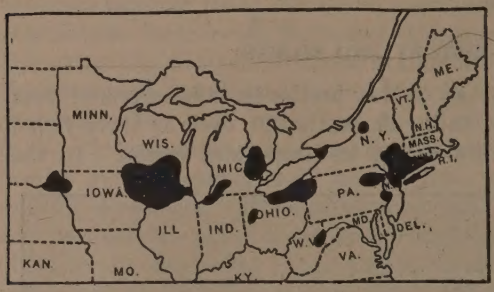


FIG. 7.—Map showing area of greatest abundance of "Brood A" of white grubs.

FIG. 8.—Map showing area of greatest abundance of "Brood C" of white grubs.

Unlike the grubs, the beetles of the different species differ as a rule in their food preferences. Certain species feed almost exclusively on the oak, others prefer the ash, and some feed indiscrimi-

nately. The trees which they ordinarily frequent in the Northern States are the oak (white and burr oaks in preference to red and black oaks), hickory, poplar, elm, willow, locust, hackberry, ash, and walnut. In certain localities the pine seems to be the preferred food. At Columbia, S. C., two species [1] have been found feeding on the longleaf pine by preference, and similar observations for these two species as well as for another [2] have been made in Alabama.

In the latitude of Indiana May beetles make their first appearance the last of April or first of May and continue to be present until the first or middle of July, the period of greatest abundance being between the middle and last of May. They swarm to the trees at

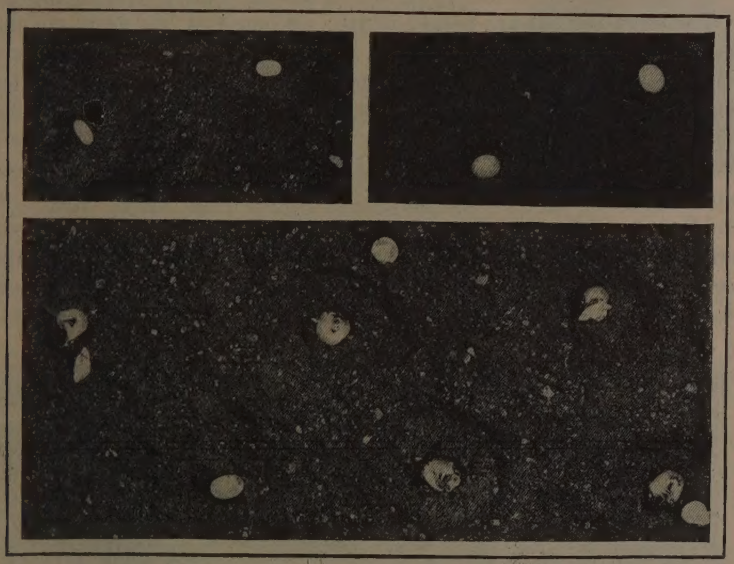


FIG. 9.—Eggs of white grubs in their natural cells: Upper left, immediately after deposition; upper right, six or seven days later; below, white grubs hatching.

dusk and remain there feeding and mating till just before dawn, when they return to the soil, only to reappear the following evening.

When abundant the beetles are capable of defoliating large acreages of timber (figs. 12 and 13). In 1911, and again in 1914, 40-acre tracts of timber were completely defoliated by the beetles in southwestern Wisconsin, northeastern Iowa, northern Illinois, and southern Michigan, and the dropping of excrement and of detached leaves at night, when the beetles were feeding, sounded like hail. The beetles, in the years of abundance, were attracted to street arc lights in great swarms, and in one small town in southwestern Wisconsin

[1] *L. prunuculina* Burmeister and *L. luctuosa* Horn. [2] *L. micans* Knoch.

the beetles accumulating beneath the 10 arc lights of the town were hauled away each morning for a period of 10 days or two weeks by the wagon load.

The beetles (fig. 2) prefer to deposit their eggs in ground covered with vegetation in the immediate vicinity of timber, usually choosing for this purpose the more elevated parts. The preference in oviposition therefore has an important bearing on the control practices, for the grubs ordinarily are found most abundant in the higher portions, especially near wooded tracts, of fields of timothy (fig. 10) and bluegrass sod, or in any ground which during the previous year was in one of these crops or in small grain, or any other ground which was covered with vegetation excepting clover during the flight of the beetles.

The eggs (fig. 9) are pearly white. When first laid they are elongate, measuring about one-tenth inch in length, but six or seven days after oviposition they become swollen and almost spherical. They are deposited in the soil at a depth ranging from 1 to 8 inches, within oval cavities in the center of balls of earth, the particles of earth forming the balls being held together by a glutinous secretion supplied by the female beetle.

After hatching the very young grubs seem to prefer decaying vegetation, although under certain conditions, especially when they are very numerous, they will attack living roots. This was the case in Wisconsin in 1911, when the young grubs, only about 2 months

FIG. 10.—A piece of sod overturned to show the white grubs underneath, Lancaster, Wis., 1912.

old, damaged timothy fields (fig. 10). The grubs do the greatest amount of damage in their second year, and to the early plantings in their third year.

GRUBS LIKELY TO BE MISTAKEN FOR COMMON WHITE GRUBS.

It is important that the grubs of May beetles should not be confused with similar but harmless grubs and with other grubs which may be injurious but which, because of different habits and life history, require different methods for their control. Probably the most universal mistake is the general belief that the common white grubs of the field and the white grubs found in manure heaps and rotten logs are identical. *The grubs of May beetles are not known to breed in manure or refuse of any kind.* The most common grubs found in manure in the Northern States are the immature forms of certain brown beetles[1] which, like the May beetles, frequent lights, and would doubtless be mistaken for the latter by an inexperienced person, but unlike the latter the beetles do not feed on the foliage of plants. The May beetle grubs (fig. 15, *a*) may be distinguished from the manure grubs (fig. 15, *b*) and from most other grubs by the presence of a double row of more or less conspicuous spines along the median line on the underside of the last body segment.

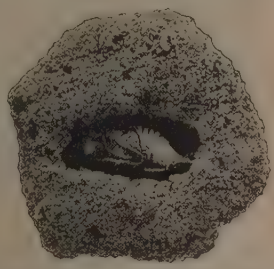


FIG. 11.—White-grub pupa in earthen cell. Natural size.

Another grub commonly mistaken for that of a May beetle is the young of the southern green June beetle, which frequently has been reported as indirectly injuring grass and other vegetation, including alfalfa, in localities south of the latitude of northern Kentucky, or even farther north along the Atlantic coast. The grub of the green June beetle seems to prefer soils more or less heavily fertilized with animal manures, and, besides, entirely unlike the common white grubs, it makes definite burrows which usually open at the surface and which it may inhabit continuously for longer or shorter periods of time. For this reason grubs of this species will come to the entrance of their burrows and even crawl out upon the ground when the land is flooded with water. This characteristic also offers a satisfactory means of controlling the grub of the green June beetle when in lawns or small areas. Again, this grub may be distinguished from the true white grubs by its general appearance and especially by its peculiar and characteristic method of crawling on its back when placed on the surface of the ground.

[1] *Ligyrus gibbosus* DeGeer and *L. relictus* Say. [2] *Cotinus nitida* Linnaeus.

NATURAL ENEMIES.

The white grubs and May beetles are preyed upon by numerous birds, mammals, and insects, all of which are more or less useful in reducing their numbers. Probably the most important of the natural enemies are the birds, especially crows and crow blackbirds. Fields of timothy sod have been literally overturned by crows in their search for grubs (see fig. 16), and in some fields the grubs were almost exterminated by them. Crows have often been observed following the plow in infested fields, eagerly picking up every grub that was unearthed. In one instance a single blackbird was observed to eat many grubs, apparently its full capacity, and then gather as many as it could hold in its beak and fly away. In this case the bird destroyed in all 20 grubs in 1 or 2 minutes. Besides crows and blackbirds, practically all of the common birds feed on white grubs or their adult forms, the May beetles. The U. S. Biological Survey has found these insects in the stomachs of 78 species of birds and 2 species of toads.

All farm fowls are fond of these insects and where possible should have the run of infested fields at the time of plowing. The turkey especially is valuable in this respect. The writer has seen infested timothy and sod fields thoroughly scratched up by these birds in their search for grubs. Chickens seldom search unplowed fields for grubs but if permitted to follow the plow will eagerly pick up every grub or May beetle exposed.

FIG. 12.—Walnut and soft maple, the former defoliated by May beetles, Galena, Ill., May 31, 1914.

FIG. 13.—Hickory and oak timber defoliated by May beetles, Platteville, Wis., June 1, 1914.

Among the native mammals which feed on the grubs the skunk is probably the most valuable,[1] and, indeed, some farmers have gone so far as to attribute the increase in these insects to the decrease in numbers of skunks, which are being rapidly killed off by the trappers. In northeastern Iowa many large land-owners observed the grub-eating habits of the skunk during the recent severe outbreak, and have signified their intention from now on of protecting this friend of the farmer.

A large number of predacious and parasitic insects have been studied. Of these it is probable that such common and generally distributed forms as certain black digger wasps,[2] and another wasp,[3] are among the most beneficial.

The Tiphia wasp larva, after devouring the white grub, forms a characteristic cylindrical-ovate, light brown, woolly cocoon about three-fourths inch in length (fig. 17), and from this the jet black digger wasp emerges the following spring or summer. The cocoon of the Elis wasp (fig. 18) differs from the Tiphia cocoon (fig. 17) in that it is elliptical, slightly longer, of a darker brown, and comparatively smooth. The adult emerging therefrom is about the same size as the Tiphia wasp, or slightly larger, and the black abdomen is transversely striped with yellow. The cocoons of both of these parasites are frequently turned out by the plow, especially in fields badly infested with white grubs. The larvæ of flies,[4] parasitic on grubs, are

[1] The domestic hog is the most efficient of all grub destroyers where it can be utilized. It is fully discussed in this connection under "Methods of control," p. 17.

[2] *Tiphia* spp.

[3] *Elis* sp.

[4] *Microphthalma disjuncta* Wiedemann and *Ptilodexia tibialis* Desvoidy.

numerous in certain localities, but since they are living within live grubs in fall, winter, and early spring, they are seldom noticed behind the plow. The larvæ of robber flies,[1] which prey upon white grubs, are slender, shining white, pointed at both ends, and about an inch and a half in length when full grown (fig. 19). They have a life cycle corresponding to that of the common white grubs in that they require three years to complete it. In certain sections of Wisconsin, Michigan, and New York they undoubtedly have been very important in minimizing the destructiveness of the grubs. When mature they issue as large flies commonly known as robber flies, bee killers, etc., and in this stage of their life are predacious on many kinds of insects. Certain parasitic flies[2] (fig. 20) attack only the beetle, usually depositing the egg within its body with its needle-like ovipositor as it flies from leaf to leaf or to the ground at night. The larva hatching from the egg gradually kills the beetle, although often the latter, if a female, is capable of depositing eggs for some days after being parasitized. Certain two-winged flies,[3] are similarly parasitic on the adult beetle but they oviposit on the beetle when it is quietly feeding on foliage at night.

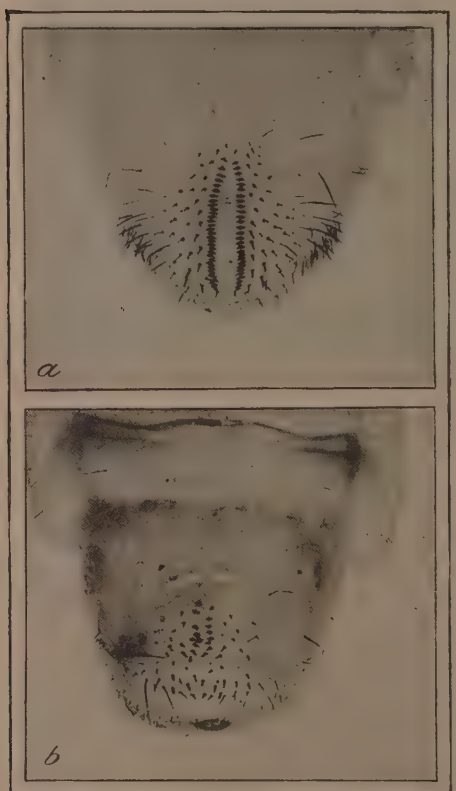


FIG. 15.—Last segments of the larvæ of (*a*) a common white grub and (*b*) a grub frequently found in manure.

Several fungous, bacterial, and animal parasite diseases have been reported attacking the grubs and beetles. Occasional outbreaks of these diseases have been observed, and it is highly probable that they serve as valuable natural checks periodically when conditions are

[1] *Promachus vertebratus* Say and *P. fitchii* Osten Sacken.

[2] *Pyrgota undata* Wiedemann and *P. valida* Harris.

[3] *Cryptomeigenia theutis* Walker, *Eutrixa exilis* Coquillett, and *Biomyia fascipennis* Townsend.

favorable. In Europe certain of these diseases have been artificially grown and used to destroy the grub, but there seems to be a divergence of opinion as to their value when used in this manner. The experience of the writer indicates rather strongly that they can not be introduced artificially with satisfactory results except under favorable weather conditions.

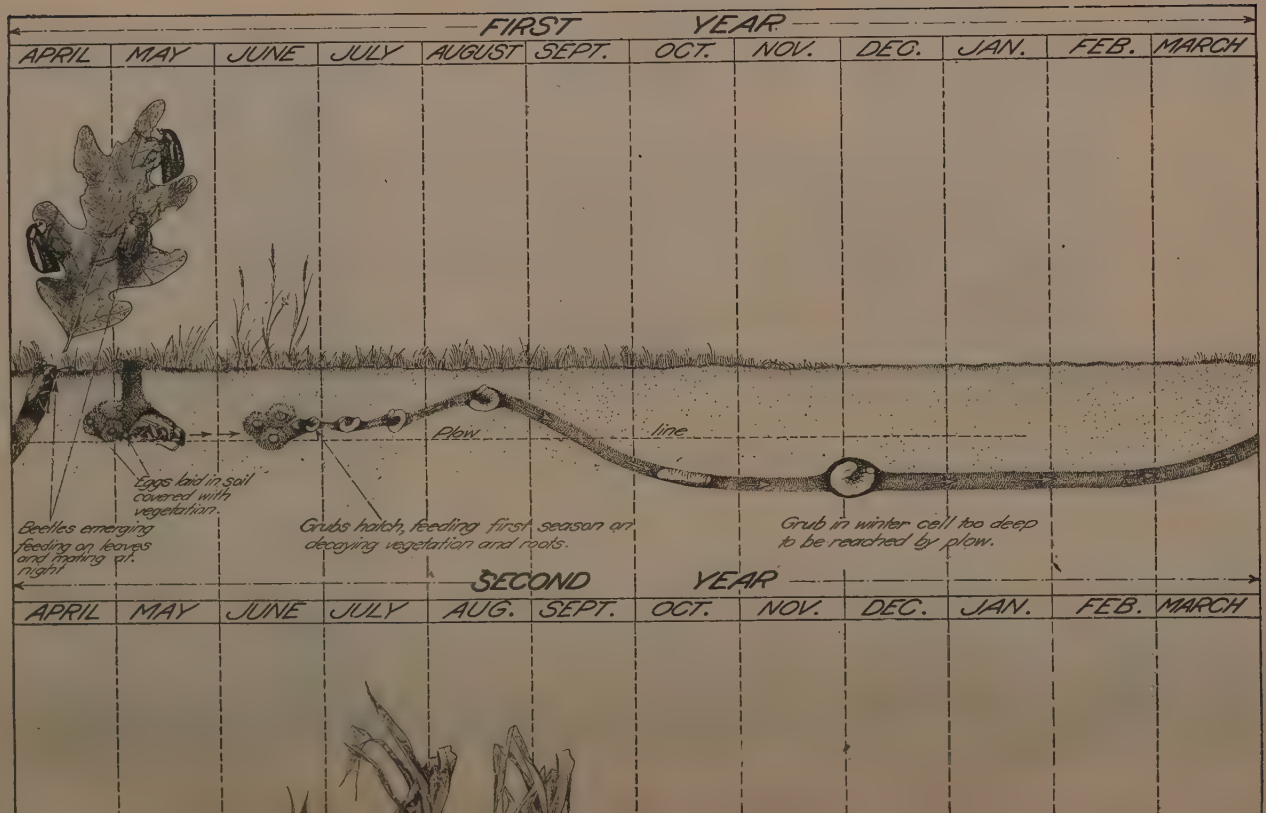
METHODS OF CONTROL.

All of the general farm practices here discussed and recommended are preventive rather than remedial, for once white grubs are present in a field of corn or other crop of large acreage there is no practical means as yet known of protecting that particular crop from their ravages. On the other hand, certain cultural and other practices will minimize greatly the damage in succeeding years.

UTILIZING HOGS AND POULTRY TO DESTROY GRUBS.

The practice of "hogging off" corn, thereby saving the labor and expense of harvesting and marketing the crop and also producing more pork from the crop, is becoming a common farm practice, the value of which has recently been repeatedly demonstrated. The utilization of hogs for the destruction of soil-inhabiting insect pests, more especially of white grubs and cutworms, however, has received little attention and seldom has been applied consistently, although pasturing hogs in grub-infested fields has been practiced occasionally for the last hundred years. The use of poultry is somewhat more restricted, since it can be utilized only when ground is being plowed

FIG. 16.—Timothy field after harvest, showing sod overturned by crows in their search for white grubs, Galena, Ill., 1912.


FIRST YEAR
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
Plow line
Eggs laid in soil covered with vegetation.
Beetles emerging feeding on leaves and mating at night
Grubs hatch, feeding first season on decaying vegetation and roots.
Grub in winter cell too deep to be reached by plow.
SECOND YEAR
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH

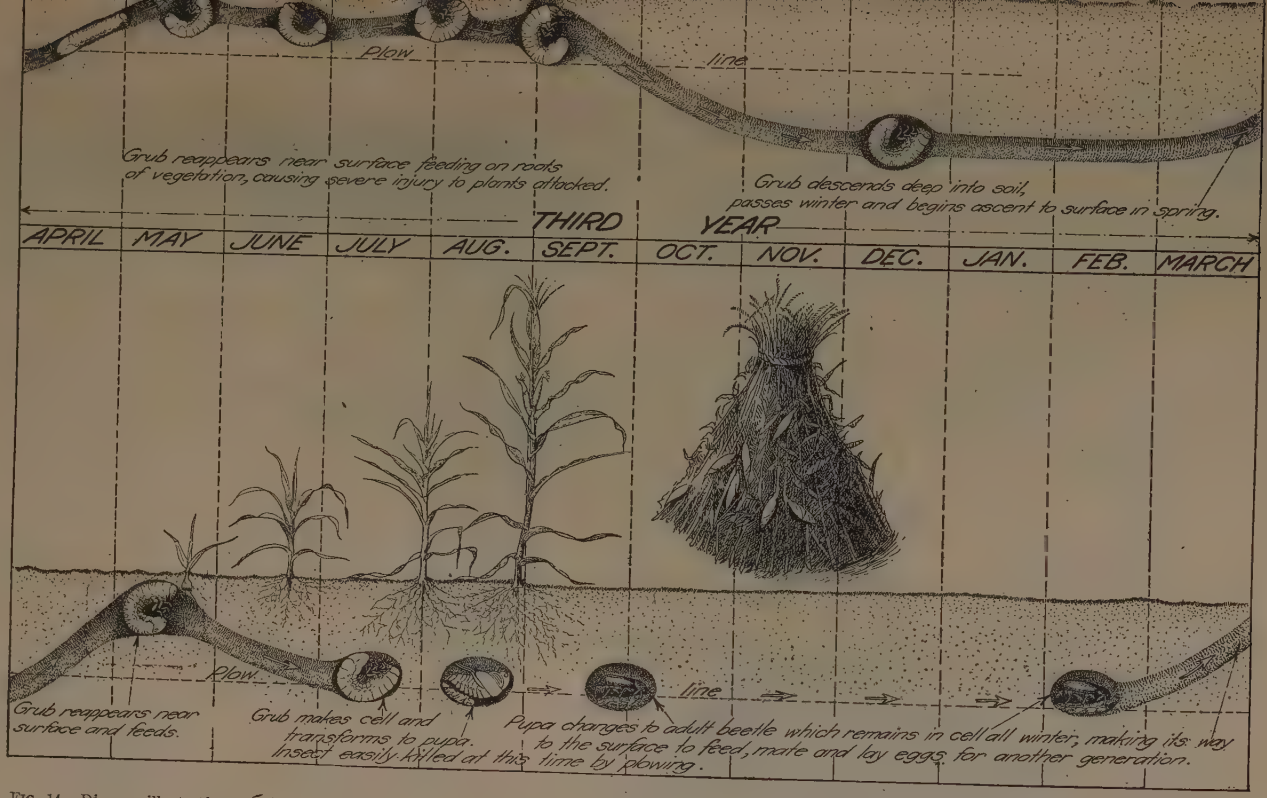

Plow line
Grub reappears near surface feeding on roots of vegetation, causing severe injury to plants attacked.
Grub descends deep into soil, passes winter and begins ascent to surface in spring.
THIRD YEAR
APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Grub reappears near surface and feeds.
Grub makes cell and transforms to pupa. Insect easily killed at this time by plowing.
Pupa changes to adult beetle which remains in cell all winter, making its way to the surface to feed, mate and lay eggs for another generation.

FIG. 14.—Diagram illustrating complete life cycle of white grubs, which covers a period of three years, and showing the periods during which they can be killed by plowing.

or cultivated, and then only in fields near the farm buildings, unless a portable poultry house, such as will be discussed later, is used.

The main objects to be gained by the practices indicated above are (1) eradication of grubs, cutworms, and probably such other insect pests as wireworms; (2) food value derived from the grubs, which is equal to a hog feed costing $25 to $35 per ton; (3) manuring the land. The United States Bureau of Animal Industry has estimated the value of manure to be $3.29 per ton in the case of hogs and $7.07 in the case of poultry.[1] When corn ground is "hogged" there is the additional advantage of a saving in labor and expense in harvesting and marketing the crop and the production of more pork from the crop.

FIG. 17.—Cocoon of a wasp, *Tiphia* sp., a parasite of the larvæ of May beetles.

EXAMPLES OF INSECT CONTROL BY HOGS AND POULTRY.

The fondness of hogs for white grubs and May beetles is well known and evidenced wherever unringed hogs have been turned into pastures (fig. 21), but a most striking example has been shown.[2] One hundred pigs and eight sows were turned into an inclosed 10-acre cornfield at Ludlow, Ill., which was badly infested with grubs, September 23. Within 20 days 86 per cent of the grubs were destroyed and in 27 days less than 1 per cent of the original infestation remained—a benefit of over 99 per cent. If the number of grubs per hill is estimated as 34.6, the count made at the beginning of the experiment, and the number of hills of corn to the acre as 3,556 (hills 3½ feet each way), it is easily calculated that the pigs destroyed something like 1,217,083 grubs in 27 days; that is, 11,278 grubs, or possibly 24 pounds, per animal. These hogs, by the way, suffered no ill effects from the continuous ration of grubs.

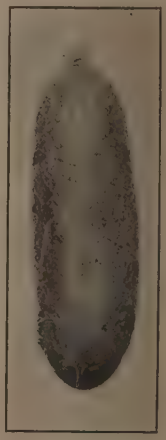


FIG. 18.—Cocoon of a wasp, *Elis* sp., a parasite of the larvæ of May beetles.

Turkeys are very fond of grubs and search diligently for them.

Poultry can be utilized to excellent advantage, especially if allowed the run of the fields during plowing or cultivation. The effective-

[1] Weekly News Letter, U. S. Department of Agriculture, v. 4, no. 17, p. 3. November 29, 1916.

[2] Forbes, S. A. On the life history, habits, and economic relations of the white grubs and May beetles. Ill. Agr. Exp. Sta. Bul. 116, p. 478. August, 1907.

ness of chickens in controlling white grubs is demonstrated by an experience at Froelich, Iowa, where the farm poultry, numbering about 150 chickens, were encouraged to follow the plow, harrow, and cultivator in a 15-acre field, badly infested with white grubs, adjoining the farm buildings. Scarcely a grub remained after a season's foraging by the chickens.

FIG. 19.—Larva of the robber-fly *Promachus vertebratus* attacking white grub.

The value of portable poultry houses, which can be transferred from field to field or to any particular part of a field, has never been demonstrated in this country, but their use was advocated in Europe for the control of the European May-beetle grubs as early as 1860.

FIG. 20.—*Pyrgota undata*, a fly parasite of adult May beetles. Enlarged greatly.

The portable houses were described as having a capacity for 200 chickens, and being furnished with perches, numerous egg-laying compartments, and a box to catch the manure. The houses were moved to the field and each morning the chickens liberated to forage in the vicinity of their quarters. They returned to their coop toward evening and the door was closed, but the house was left in

the field continuously, except during the most severe winter nights. The advantages obtained, in addition to the destruction of grubs and other insects, were the utilization of a mass of grain left after harvest and the production and saving of the valuable manure.

VALUE OF WHITE GRUBS AND MAY BEETLES AS ANIMAL FOOD.

Through the cooperation of Mr. W. J. Jones, State Chemist of Indiana, standard chemical feeding analyses of white grubs and May beetles of the genus Lachnosterna have been made and these, together with an analysis of dent corn for comparison as given by Prof. W. A. Henry,[1] follows:

Analysis of dent corn, compared with white grubs and May beetles.

Material.	Grubs.[a]	Beetles.[b]	Corn.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	59.9	69.4	10.6
Crude fat	3.1	4.9	5.0
Crude protein	11.1	20.1	10.3
Crude fiber	1.6	3.7	2.2
Crude ash	2.0	1.6	1.5
Nitrogen-free extract (carbohydrates)	2.3	10.3	70.4

[a] One and two year old grubs collected behind plow in fall of 1916.
[b] Recently matured beetles collected behind plow in fall of 1916.

In comparison with such a standard feed as corn it will be noticed that in grubs the percentages of fat and protein, the most valuable foods in feeding material, about equal the percentages of these constituents in corn, while the percentages in beetles run much higher. The carbohydrates, on the other hand, are deficient in the insects; and this would indicate that the feeding of corn in connection with pasturing hogs in grub-infested land, or, better, "hogging down" corn if the infested field is in corn, is desirable and a good practice.

In the white-grub infested areas there is an average of 106,680 grubs per acre, and the weight of the grubs during the fall of their destructive season averages 1 gram each, that is, 454 to the pound, the beetles weighing slightly less. Thus it may be estimated that each infested acre contains approximately 235 pounds of grubs which have a value as hog food of more than $3, that is, $30 for ten acres.

VALUE OF WHITE GRUBS AND MAY BEETLES AS MANURE.

In addition to the value of grubs and May beetles as hog and poultry feed, the value of the manure produced should also be considered. As a general criterion the money value of hog manure has been estimated, as indicated above, at $3.29 and of poultry manure at $7.07 per ton. It is said[2] that during the life of the animal 85

[1] Henry, W. A. Feeds and Feeding.

[2] Good, E. S. The growing and fattening of hogs in the dry lot and on forage crops. Ky. Agr. Exp. Sta. Bul. 175, p. 332. April, 1915. (Statement of Dr. H. S. Grindley quoted.)

per cent of the fertilizing constituents ingested by hogs as food is eliminated by the system in the urine and feces, the percentage being greater for mature individuals. By simplifying the protein constituents we find that the grubs contain 1.78 per cent nitrogen and the beetles 3.22 per cent, and since each heavily infested acre is estimated to contain 24 pounds of grubs or 16 pounds of May beetles we may figure that approximately 3½ pounds of nitrogen

FIG. 21.—Hogs rooting for grubs in cornfield referred to on page 18. Photograph furnished by Dr. S. A. Forbes.

alone would be replaced in the manure produced by the hogs eating the grubs, and 4½ pounds if the food were in the form of beetles. The ash, constituting 2 per cent of the grubs and 1.6 per cent of the beetles, is heavy in phosphoric acid, but the exact amount of this and other fertilizing elements has not been ascertained.

EFFECT RESULTING FROM CONTINUOUS GRUB DIET.

Occasionally reports of harmful effects to hogs from a continuous grub diet have been received, but it has not been possible to verify them. On the other hand, well-informed farmers and expert swine raisers who have had experience in pasturing hogs on grub-infested land disclaim any harmful or poisonous effects from such practices.

Likewise poultry may be fed white grubs and May beetles without any harmful results and without producing any noticeable effect in the eggs, such as is noticed when chickens feed continuously for several days on such caterpillars as the army worm. No difference in taste has been found in European tests between eggs from grub-

nourished hens and those from others. On the contrary, the eggs of the former had better yolks for thickening and were worth three of the others to color sauces. No unfavorable effects resulted from the use of either grubs or May beetles as chicken feed, except in the case of dried beetles mixed with bread or potatoes, which proved too exciting for the older fowls.

OBJECTIONS MADE TO GRUBS AS ANIMAL FOOD.

Three objections have been raised to the use of unringed hogs in grub-infested fields, most of which apply only in cases of pasturing on sod land. These objections are (1) lack of hog-tight fences; (2) rooting up of pasture land; (3) possible infestation with the giant thorn-headed worm,[1] an intestinal worm affecting hogs.

The first objection has been answered, for it has been shown that the value of the grubs as hog feed almost pays for the cost of fencing—at least temporary fencing.

Our observations show that an infested pasture, although overturned by rooting hogs, reseeds itself the following season with no ill effect other than a roughing of the surface, which is of little significance.

The last objection, relative to possible infestation with the giant thorn-headed worm, is of considerable importance. The white grub is one of the intermediate hosts of this worm, which seems capable of entering hogs only by being taken into the body with grubs eaten. No trouble will result from these worms, however, if hogs which have never been pastured are used in fields which have not been previously pastured with hogs within three years. Care should be taken to prevent brood sows from running in fields which are likely to contain grubs infested with thorn-headed worms, that is, in fields which have been hog-pastured the previous season or two, but hogs being fed for market can, with the possible exception of very young pigs, be pastured with less regard for the past history of the field, since they will be marketed before the effects of the worms, if any are present, become harmful.

SUGGESTIONS FOR THE USE OF HOGS FOR WHITE-GRUB CONTROL.

In the white-grub infested districts hogs may be used to advantage each year and in almost every season of the year. Figure 14 illustrates graphically the life cycle of this insect and should be used as a guide in pasturing hogs on infested ground. It should be noted that the grubs ordinarily go rather deep into the ground to pass the winter, usually starting their downward migration by October 10, so that it is desirable to practice fall pasturing previous to this date.

[1] *Echinorhynchus gigas.*

During the flight of the beetles hogs should be pastured in timber lots or fields adjoining, that they may have an opportunity to destroy the beetles. In the fall of the year the beetles are abundant and the hogs should be pastured in small-grain stubble, timothy, bluegrass, or weedy lands, for here the beetles have laid their eggs and the young grubs are to be found. The year following an abundance of beetles, which is the year the grubs are most destructive, pasturing after the first of May is desirable when it can be done conveniently, but before this date the effect of pasturing on the grub population is not so evident, since the ground is usually quite hard and the grubs still in their winter quarters, often 2 feet or more below the surface. It has been shown that "hogging" corn is profitable and if the ground contains grubs it will be especially profitable for pasturing, since the combination of corn and grubs offers a fairly well-balanced ration. The third year, when the grubs mature and change to beetles, the hogs may be utilized at any season after May 1, and it is especially desirable to pasture them in ground which showed an abundance of grubs the preceding year.

As has already been inferred, poultry can be used to advantage at any time of the year, except possibly during the winter months when the grubs are deep in the ground, by permitting them to follow the plow, cultivator, and harrow whenever possible.

In pasturing hogs it is well to keep in mind the following points: (1) Accustom the hogs to corn and grubs gradually, especially the former; (2) a water supply should be considered; (3) it is best to fence off a single portion of the field at a time in order to make the eradication of grubs uniform and complete and to avoid waste in "hogging" corn; (4) a supply of salt should be available to the animals at all times.

ROTATION OF CROPS.

Rotations are especially important in avoiding white-grub injury. A rotation of oats or barley, clover, and corn has proved very satisfactory in some sections. Ground which is in corn or has a heavy stand of pure clover during the year the beetles are flying ordinarily will contain few grubs, since the beetles will not seek such land for laying their eggs, but prefer land in small grains or timothy, or covered with weeds. Land which is in oats, barley, or wheat during the flight of the beetles will contain many grubs, but if the grain is followed by clover, which is one of the least susceptible crops, the grubs will scarcely injure the clover. It is asserted that clover winter-kills badly in southern Wisconsin, northern Illinois, and similar latitudes. but there is reason to believe that this is because the clover is not sufficiently vigorous to survive severe winters, and the remedy is liming or otherwise treating the land so as to grow a vigorous stand of clover. Aside from this rotation, it is desirable to arrange the crops so that the

least amount of land will be in timothy and small grain the year the beetles are abundant, and the following year to plant corn on corn ground, and use for small grain and timothy the ground which was in these crops the previous year. Where hogs can be pastured on the land the fall previous to planting, as under the conditions discussed in the preceding paragraphs, less regard need be had to the selection of crops, since a thorough pasturing by hogs will practically eradicate the grubs.

FALL PLOWING.

Where it is impractical to pasture hogs in an infested field or to follow the prescribed methods of rotation, some good can be accomplished by plowing the ground in the fall. Fall plowing previous to the time the grubs go deep into the ground to pass the winter, i. e., previous to October 10, as a rule will destroy many of the grubs and should be practiced whenever possible but should not be considered a panacea for the grubs. Ordinarily the best time to plow with this object in view is between October 1 and October 10. The main point to be remembered is to plow before the grubs go below the plow line and as short a time before this as can be done.

Summer and fall plowing the year the grubs are changing to beetles, that is, in 1918 for brood C and in 1919 for brood A, is of special value, and every piece of ground which contained grubs in their injurious stage the previous year should be plowed, if at all possible, as soon after July 15 as is practicable, and the sooner this is done after that date the more thoroughly will the pests be eliminated. A plow which will *break up the soil* as it is overturned should be used, or if this is not possible the ground should be deeply disked after plowing in order to break up the soil and disturb the insects in it. Whenever a grub-infested field is being plowed, harrowed, or cultivated where chickens are available, these should have the run of the field.

COLLECTING THE GRUBS AND BEETLES.

Where it is possible to secure cheap labor, collecting the grubs after the plow is practicable, especially where the grubs are numerous. In Europe children are often employed to gather grubs in this manner and to collect the beetles.

Collecting the cockchafer,[1] a beetle very closely related to the May beetle, is a common practice in European countries, but so far as known no attempt to collect May beetles on an extensive scale in the United States has ever been made. Three methods may be employed in beetle destruction: (1) Collecting from plants upon which they feed at night, (2) trapping at lights, and (3) poisoning their food plants.

[1] *Melolontha vulgaris* Linnaeus.

In Europe beetle collecting has proved of value largely because the years of abundance of the beetles have been definitely known in advance, while in America this has not been the case. Now, however, there is proof that the beetles occurring in such abundance in many parts of the United States in 1914 (the parents of the destructive generation of grubs in 1915) have a life cycle of three years, and it is reasonably certain that they will continue to be exceptionally abundant in these regions every three years unless killed off by their natural enemies, by artificial means, or by unfavorable climatic conditions. Beetle collecting in the Old World has also proved practicable, first, because of the organized cooperative movement among the farmers for the collection of the beetles; second, because a small bounty is paid for the beetles; and, third, because of laws which in some countries require each farmer to collect a certain quantity of the grubs or beetles each year. Only where whole communities or neighborhoods cooperate in the work is it effective.

In collecting from food plants large cloth sheets are placed under the tree and the latter jarred, or in the case of large trees individual branches may be shaken by using a long pole provided with a hook at the end. The beetles are then gathered up from the sheet and placed in cans, bottles, or boxes and afterwards killed with the vapor of carbon disulphid. Killed in this manner they may be fed to chickens, pigs, etc., but if they are not to be used for such purposes they may be killed by dropping them in cans containing water and just enough kerosene oil to cover the surface. As a rule beetles are most abundant on the oak, walnut, poplar, hackberry, willow, ash, and elm. Collections may be made at any time during the night, but the best time for this work is in the early morning, before 4.30 o'clock, at a time when the beetles are easily jarred from the foliage. It is essential that collecting be begun as soon as the beetles appear in the spring—that is, before the beetles have begun to lay their eggs—and it should also be borne in mind that each female beetle destroyed early in the season means the destruction of from 50 to 100 grubs which she might have produced.

Light traps have not as yet proved satisfactory as a means of control against May beetles, the prime objection to this method being that the light attracts the males to the almost total exclusion of the females. Further tests with this method must be made, and it is possible that the light may prove attractive to the female beetles in years of unusual abundance if placed close to the trees or shrubs upon which they feed.

SPRAYING.

Spraying trees upon which the beetles feed, with Paris green, arsenate of lead, or similar arsenical, is effective against the beetles, but ordinarily this method is impracticable owing to the large size of the trees, which would necessitate large and expensive power sprayers. After more definite knowledge of the preferred food plants has been obtained it may be found practicable in some localities to plant low-growing trees and shrubs about fields as traps for the beetles, which might then be destroyed by spraying.

SPECIAL DIRECTIONS.

In those regions in which the grubs were abundant and destructive in known years certain special directions and precautions may prevent a repetition of damage. As has already been stated, the parents of the grubs of 1915 appeared in the spring of 1914 and laid the eggs which hatched into grubs. Practically no damage occurred that year, but in 1915, when about half grown, the grubs caused great loss. These grubs continued active in the spring of 1916 and injured certain early plantings, but by early June most of the grubs became more or less inactive and later changed to the dormant or pupa stage, transforming into beetles about August. They remained in the soil as beetles over winter, appearing above ground in the spring of 1917.

The accompanying table (p. 28) will assist in preventing grub injury, especially in those localities (see figs. 7 and 8, p. 8) where the grubs make their appearance regularly each third year.

IN THE LAWN.

Lawns destroyed by grubs should be resodded or reseeded, the old sod being first removed and the grubs gathered by hand, although if poultry, especially turkeys, are allowed the run of the ground as the old sod is being removed, they will do the work in a thorough manner. If the infestation is slight, liberal applications of a commercial fertilizer will assist the grass in overcoming the grub injury. Experiments in Europe with a European white grub have demonstrated that carbon disulphid injected into the soil at a depth not exceeding 6 inches, at the rate of 1 to 1½ ounces in six or eight holes per square yard, will considerably diminish the number of grubs. It appears very probable that this method would prove satisfactory for our white grubs when they appear in lawns. In fact, the experience of the department indicates that carbon disulphid can be used with profitable results. Care should be taken not to water the treated ground for 24 hours after application, since a saturated soil prevents the disulphid from evaporating, thus making it less effective and rendering the grass roots liable to injury. *In using carbon disulphid care should be exercised never to permit a spark of fire to come near it, for it is extremely inflammable, and its vapor mixed with air in certain proportions is*

explosive. Holes in which the carbon disulphid is injected should be closed with a plug of soil or sod immediately after the injection, to prevent the escape of the fumes.

Kerosene emulsion has been recommended repeatedly as an effective grub insecticide. The department's tests indicate that it is satisfactory against grubs if thoroughly applied when the grubs are near the surface and the emulsion then washed well into the soil by copious sprinkling. Watering washes the emulsion from the grass and prevents burning and at the same time permits the insecticide to penetrate more thoroughly into the soil. For small areas an ordinary sprinkling can may be used in applying the emulsion, but for larger areas the use of a force pump will save time and labor, a wide sprinkling can type of nozzle or "rose" being used, so that the lawn can be uniformly drenched in the shortest possible time.

Kerosene emulsion is prepared as follows: One-half pound of hard soap or 1 quart of soft soap, preferably fish-oil, rosin-soda, or rosin-potash soap, is dissolved in 1 gallon of boiling water, and while hot 2 gallons of kerosene are added and the mixture thoroughly emulsified. This may be done most easily and thoroughly by churning for about 10 minutes with a spray-pump, the nozzle being turned back into the liquid. When thoroughly emulsified the preparation will have the consistency of thick cream, and the oil will not separate. Danger of injuring plants is great if the mixture is not well and thoroughly made. For a 7½ per cent emulsion add 25 gallons of water to the above stock solution and mix thoroughly. It is desirable to use soft water both for the stock and for diluting, but where this is not obtainable the water should be softened by adding lye or sal-soda. A much better emulsion, apparently more effective and more easily made, is prepared by the use of fusel oil. It is prepared by dissolving 3½ pounds of fish-oil soap in enough water to make a gallon, adding 1 quart of fusel oil and then 2 gallons of kerosene. When this is churned thoroughly and emulsified, add 25 gallons of water, to make approximately a 7½ per cent emulsion.

It might be mentioned here that carbon disulphid may be injected with excellent results into the holes of the grub of the southern green June beetle, which is frequently quite injurious to lawns and golf greens in the Southern States. Kerosene emulsion likewise has given excellent results against this grub.

TABLE SHOWING WHAT TO DO AT EACH STAGE OF THE WHITE GRUB.

(1) HEAVY FLIGHTS OF MAY BEETLES.

WHEN TO BE EXPECTED.	WHAT TO DO.
Brood A: Previous heavy flight was in 1917; the next heavy flight can be expected in May, 1920. Brood C: Previous heavy flight in 1916; the next heavy flight can be expected in May, 1919.	Use lantern traps during beetles' flights. Spray trees with an arsenical, such as Paris green or arsenate of lead, to destroy beetles feeding thereon. Plow grass and small grain land previous to October 1, to destroy young grubs recently hatched from eggs laid by May beetles.

(2) SMALL GRUBS ABUNDANT IN THE FALL.

Brood A: Small grubs were last abundant in the fall of 1917 and are to be expected in the fall of 1920. Brood C: Small grubs were last abundant in the fall of 1916 and are to be expected in the fall of 1919.	Plow thoroughly previous to October 1. Seed such land to small grain or clover for the following year. Do not plant corn or potatoes on such land the following season. Pasture hogs and allow chickens to run the fields when cultivated.

(3) SMALL GRUBS ABUNDANT IN THE SPRING.

Small grubs abundant in the spring indicate heavy damage during the coming summer, as these small grubs are the holdovers from the eggs laid the previous year and will be large enough to become very destructive to live roots. Brood A, destructive in 1918; Brood C, destructive in 1917.	Seed such land to small grain or clover. Do not plant corn or wide-row crop in such land. Put corn, potatoes, field beans, etc., on ground clean-cultivated the preceding year. Pasture hogs on infested ground. 1918 for Brood A; 1919 for Brood C.

(4) LARGE GRUBS ABUNDANT IN THE FALL OR SPRING.

Brood A: Fall of 1918; spring of 1919. Brood C: Fall of 1917; spring of 1918. Large grubs in the fall or spring indicate that the grub is about to go into the pupa stage and start its new 3-year cycle. These large grubs may be expected to do some damage, but by the middle of June they become dormant and begin to pass into the pupa and underground beetle stages.	Plow infested land about October 1 in fall of 1918 for Brood A and in fall of 1920 for Brood C. Delay planting until 15th or 20th of May, or a little later if practicable. Ground with large grubs in spring should be plowed as soon after July 15 as practicable, as indicated below. Pasture with hogs when possible.

(5) BEETLES OR PUPÆ IN THE GROUND IN SUMMER.

These should be found in the summer of 1919 for Brood A and in the summer of 1918 for Brood C. May be expected in all ground containing large grubs or where damage occurred the previous season.	Pasture with hogs where possible. Plow thoroughly, so as to break the clods, any time after July 15; the sooner after that date the better. 1919 for Brood A; 1918 for Brood C.